SHAPLAND

Construction & Calibration
of a Twist Drill Dynamometer

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CONSTRUCTION AND CALIBRATION OF A TWIST DRILL DYNAMOMETER

BY

EARL PAGE SHAPLAND

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Earl Page Shapland

ENTITLED Construction and Calibration of a Twist Drill Dynamometer

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

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B. W. Benedict
Instructor in Charge

APPROVED: C. R. Richards

HEAD OF DEPARTMENT OF Mechanical Engineering

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THE CONSTRUCTION AND CALIBRATION OF A TWIST DRILL DYNAMOMETER

With the introduction of high speed twist drills in modern machine shop practice comes the problem of their relative economy with that of the slow speed carbon drill which is still used to a very large extent.

To obtain data upon which the relative economy of these drills could be compared, T. J. Schance designed and built a twist drill dynamometer for his thesis in 1912. As the economy of the drill depends upon the; first cost of the drill, the durability of the drill and the operator's time, this machine was so designed that this data could be obtained. This machine was also designed with the view of obtaining the power necessary to operate different drills, and as this power depends upon--; the speed, the feed and the angle of the drill, these may be kept constant and the drills compared in this way.

Description of the Dynamometer---

The dynamometer consists mainly of two oil reservoirs or compression chambers, one for the downward thrust and the other for the torque. The magnitude of the pressures of these forces on the oil is transmitted to two recording guages, one for each reservoir.

The larger reservoir is located in the main casting of the dynamometer base. It is 11 $\frac{21}{32}$ inches in diameter and contains about one gallon of fluid. This reservoir is for the purpose of recording rhe downward thrust of the drill. Across the top of this reservoir and fastened to the sides, to form an air tight chamber, is a rubber diaphram thru which the pres-

sure is transmitted through the medium of the fluid to the guages. Upon this diaphram rests a disc having a diameter slightly less than that of the inner diameter of the reservoir. Resting on this disc and supporting another disc, on which the test piece is clamped, is a large end thrust ball bearing which allows the upper disc free to rotate in the direction of the rotation of the drill and at the same time transmits the downward thrust to the reservoir of oil below. This ball bearing is of the finest German make and provides rotation with practically negligable friction. Projecting from the upper disc is a radial arm which transmits the torque of the drill to a vertical reservoir at the left. This reservoir is constructed similarly to the larger one. It has a diameter of 4 $\frac{11}{16}$ inches and a capacity of about one pint of fluid. This reservoir is placed in a vertical position with a rubber diaphram across the front. A small cast iron pressure plate of smaller diameter than that of the inner diameter of the reservoir presses upon the diaphram thus transmitting the pressure to the guage. This reservoir is not a part of the base but is a finished casting bolted to the base of the dynamometer.

The dynamometer is made entirely of cast iron excepting the end thrust ball bearings. The base is unfinished except the upper edge of the large reservoir on which a metal ring is bolted and holds the rubber diaphram in place. The face of the vertical portion on which the smaller reservoir is fastened is also machined.

To hold the test pieces of cast iron in place, upon the upper disc, is bolted a casting whose section has the appearance of an H. The test piece being clamped into the upper portion by means of two set screws.

Guages---

The guages used on this dynamometer are of special design and are supplied by the Bristol Guage Co., of Waterbury, Conn. They are of the flattened eleptical coil spring type. As the torque is a great deal less than the downward thrust, guages of corresponding range were made. The torque guage has a range of eight lbs. per sq. in., while the thrust guage ranges from 0 lbs. per sq. in. to 25 lbs. per sq. in. The drill spindle is connected by means of cords to the guage dials so that movement of the drills causes a corresponding rotation of the dial, giving an autographic record of the downward movement of the drill on the record of the downward movement of the drill on the record card. Mechanically this is accomplished by extending the dial shafts through the back of the guages about three inches and mounting them on small pulleys to receive the cords from the drill spindle. The cords are given a few turns about the pulley and weights fastened to the cord ends which cause rotation of the dials when the drill spindle is moving upward. With the drill is moving downward action of the cords on the pulleys is reversed and the dials are rotated in the opposite direction. This mechanism gives a record card with abscissae proportional to movement of drill.

Method of filling reservoir.

To obtain the correct pressures the reservoirs must be completely filled with fluid in such a manner that no air may be pocketed in them. This was accomplished by filling the reservoirs very gradually and giving the air time to escape through the outlet. The dynamometer was tipped forward until the guages were in a horizontal plane. Two 1/2 inch pipes were then fitted to the openings at 1 and 2, Fig. 2, these pipes were about four feet long and were used to give head to the fluid that it might press

out the air more readily. The fluid was gradually poured in, giving it time to let the air bubble out. The diaphram was also pressed in at various intervals causing the air to bubble out quite rapidly. After the reservoirs were filled the dynamometer was left standing in this position for several hours that the air may gain free access to the atmosphere. The valves at 1 and 2 were then closed, the pipes removed and the openings closed.

Calibration---

Before any accurate data could be obtained the dynamometer had to be calibrated and calibration curves drawn.

To calibrate the thrust guage, the dynamometer was placed in a Riehle testing machine and loads placed upon the upper disc over the large reservoir varying from 0 to 2800 lbs. with increments of about 200 lbs. These loads were taken off with larger increments of about 500 lbs. The points were plotted with the loads as abscissæ and the readings as ordinates. These gave a curve very nearly a straight line.

In the calibration of the torque guage a more simple method was used. The dynamometer was set upon the working bench. By means of a knife edged hook, a cord was fastened to the radial arm, then over a pulley to a weight holder. Weights of five lbs. were placed on the lower end of the cord and their various readings taken and recorded. These increments were placed on up to one hundred ft. lbs. Readings were taken in both ascending and descending increments. A calibration curve was drawn for the torque with the load as abscissæ and the readings as ordinates which gave a very good curve especially at the points where the torque of the drill came.

Construction---

To fit the dynamometer up that tests might be made several small tasks had to be completed. One of the larger ones being that to fix up a bracket for the dials. This rack was made of strips of iron two inches wide and three-eight inches thick. They were forged to shape, bolted to the base and rivet-ed together. The guage was fastened to the bracket by means of small stove bolts.

The largest and more important task completed was that of arranging pulleys in such a manner that the downward motion of the drill would be transmitted to the dials uniformally. This was obtained by fastening a piece of iron by means of a cap screw to the spindle at 3. Fig. 1. Directly above this iron and bolted to the drill at 4 was an angular piece of iron in which an indicator pulley was fitted. This pulley was placed in such a position that the traverse of the cord for the various positions of the drill would always be in a vertical line. At the back and above the radial arm a forged bracket 5 was bolted; to this bracket were fitted two indicator pulleys. This bracket was placed in such a position that the indicator pulleys would be in a vertical line with the pulleys of the dial at 6 and 7. Fig. 2.

The string was first fastened at 3 then up thru the pulley at 4 and then tied to a small ring. To this ring two other cords were fastened, one leading thru the indicator pulley at 8 and then down to the pulley at 6 on the torque guage Fig. 2. The other leading over the pulley at 9 then down to the pulley at 7 on the thrust guage. These strings made three complete turns around the guage pulleys and then fastened to weights 9 and 10

which hung below. Then as the drill was fed downward the weights were lifted and the friction of the cords turned the pulleys on the guages on which the dials are fastened.

Manner of conducting the tests---

The cards were first placed in position on the dial with the drill point resting on the test piece. The power was then turned on and the feed clutch thrown in. After the drill had been cutting with its entire edge the speed was taken from the drill spindle directly. As the power was transmitted thru several clutches it became necessary that the positive speed be taken from the drill spindle. The position of the drill was marked at the beginning and after it had drilled a depth of two inches the drill was removed from the hole and the power shut off. Tests were made of the same drill in cast iron--varying the feed for each test and keeping the speed nearly as constant as possible.

Method of Calculation--

As the dials which were furnished with the guages were not calibrated the same as the dynamometer, it was necessary to make some arrangement for reading the values of the ordinates of the recorded curve. This was done by means of a templet made of tracing-cloth with the correct calibration of the machine upon it. These templets were divided into seventeen equal parts and altogether representing two inches travel of the drill. These templets were placed over the curves drawn and the values of the ordinates taken and recorded. To obtain the mean value of the ordinate the sum of half of the first plus the sum of the intermediate ones, plus half the last, was divided by the total number of ordinates crossed by the curve. Templets were made both for

the torque and thrust curves.

The comparison of the drills was based upon the number of foot pounds necessary to drill a one inch hole, two inches deep.

The total horse power is given by the horse power of the thrust plus the horse power of the torque. The thrust horse power is given by the lbs. times the distance in feet divided by 33000 ft. lbs. The distance traversed is the feed in feet times the R. P. M. of the drill. The horse power of the torque is again the product of the torque in pounds times the distance in feet divided by 33000 ft. lbs.

To obtain the duty, which is based upon the number of ft. lbs. required to remove one cubic inch of material, multiply the horse power by 33000 ft. lbs. and divide by the area of the drill times the feed in inches per minute.

Sample Calculations---

$$\text{H. P.} = \frac{\text{Feed (ft. per Min.)} \times \text{Thrust (lbs.)}}{33000} + \frac{\text{R.P.M.} \times \text{torque} \times 2\pi}{33000}$$

$$\text{H.P.} = \frac{1396 \times .198}{33000} + \frac{21.08 \times 238 \times 6.28}{33000} = 1.041 \text{ H.P.}$$

$$\text{Duty} = \frac{\text{H.P.} \times (33000)}{\text{Area of drill (sq. in.)} \times \text{feed (inches per min)}}$$

$$\text{Duty} = \frac{1.041 \times 33000}{.7854 \times 2.38} = 18350 \text{ ft.lbs.}$$

Discussion---

The results obtained were fairly consistent for the same drills keeping the feed and speed constant,which goes to show the accuracy and sensitiveness of the apparatus. As the feed was increased and the speed kept constant a larger horse power was required and the duty increased accordingly. With the same feed and varying the speed of the drill the horse power increased with the speed and duty increased also to a lesser degree. For the various drills the horse power and duty varied slightly for the same feeds and speeds. Tests of the carbon drill were made only at slow speed but the horse power required to operate them was about one-half of the high speed drills at twice the speed, showing that the time saved by the use of the high speed drill is off set by the increased horse power required to operate it.

In the test conducted with the helical fluted drills the torque and thrust remained fairly constant after the drill had cut to full size. But in the tests conducted with the straight fluted drill the torque and thrust steadily increased as the drill was fed downward. This increasein torque and thrust was caused by the chips collecting along the drill and not being carried out as in the helical fluted drill.

The one great fault of conducting these tests was the cast iron test pieces. The greater number were full of small blow holes and in some instances blow holes of one inch in diameter were struck. When the drill struct these blow holes it caused the torque to vibrate over a large range and at the same time increased it materially. The thrust would drop off to a large extent and nothing could be told of its proper value. A large number of tests had to be discarded for this reason and in some tests that were taken a

number contained small blow holes. Other test pieces contained spots of harder metal which came from melting scrap iron with the pig. When attempting to test these pieces the clutches on the drill press would slip and the drill would not operate at a high speed.

Summing up all the conditions under which the dynamometer operated it can be said that it showed itself to be sufficiently sensitive and accurate to satisfy the demands of drill tests. If proper test pieces were obtained the dynamometer would give excellent result from which the comparison of drills may be obtained.

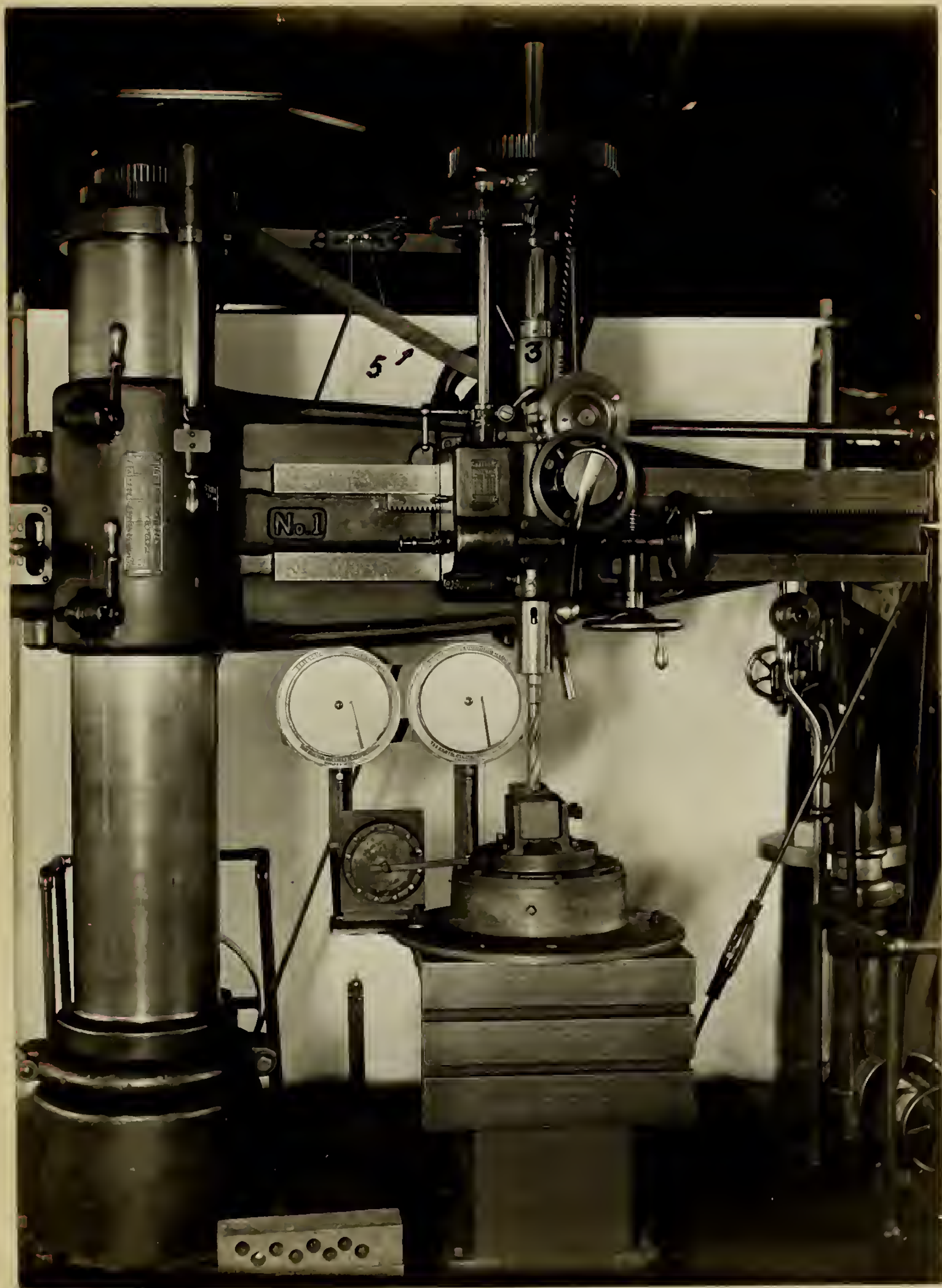


Fig. 1.

Front view of dynamometer under working conditions.

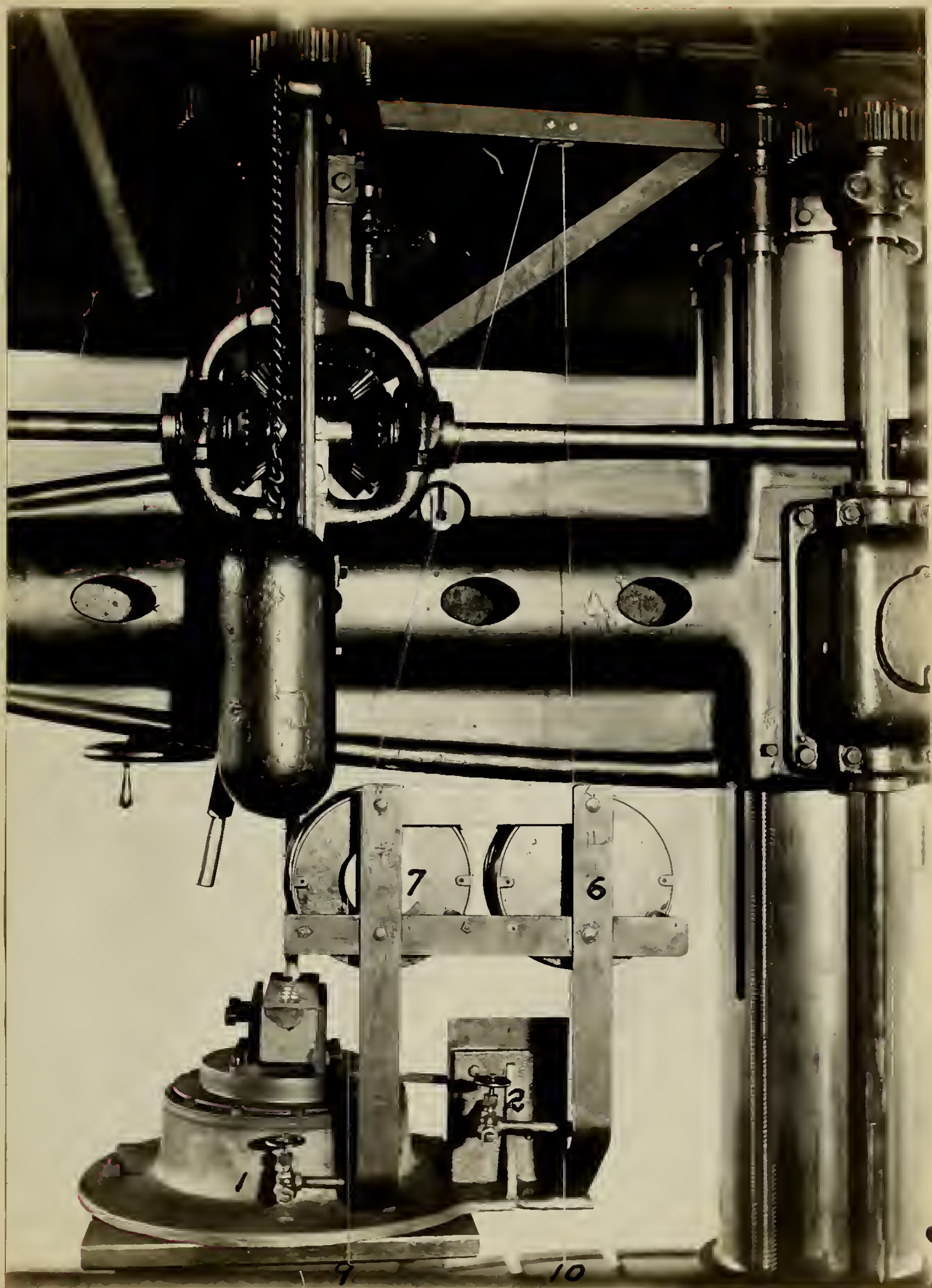


Fig. 2.

Rear view of dynamometer under working conditions.

Fig. 3.

View of details of dynamometer.

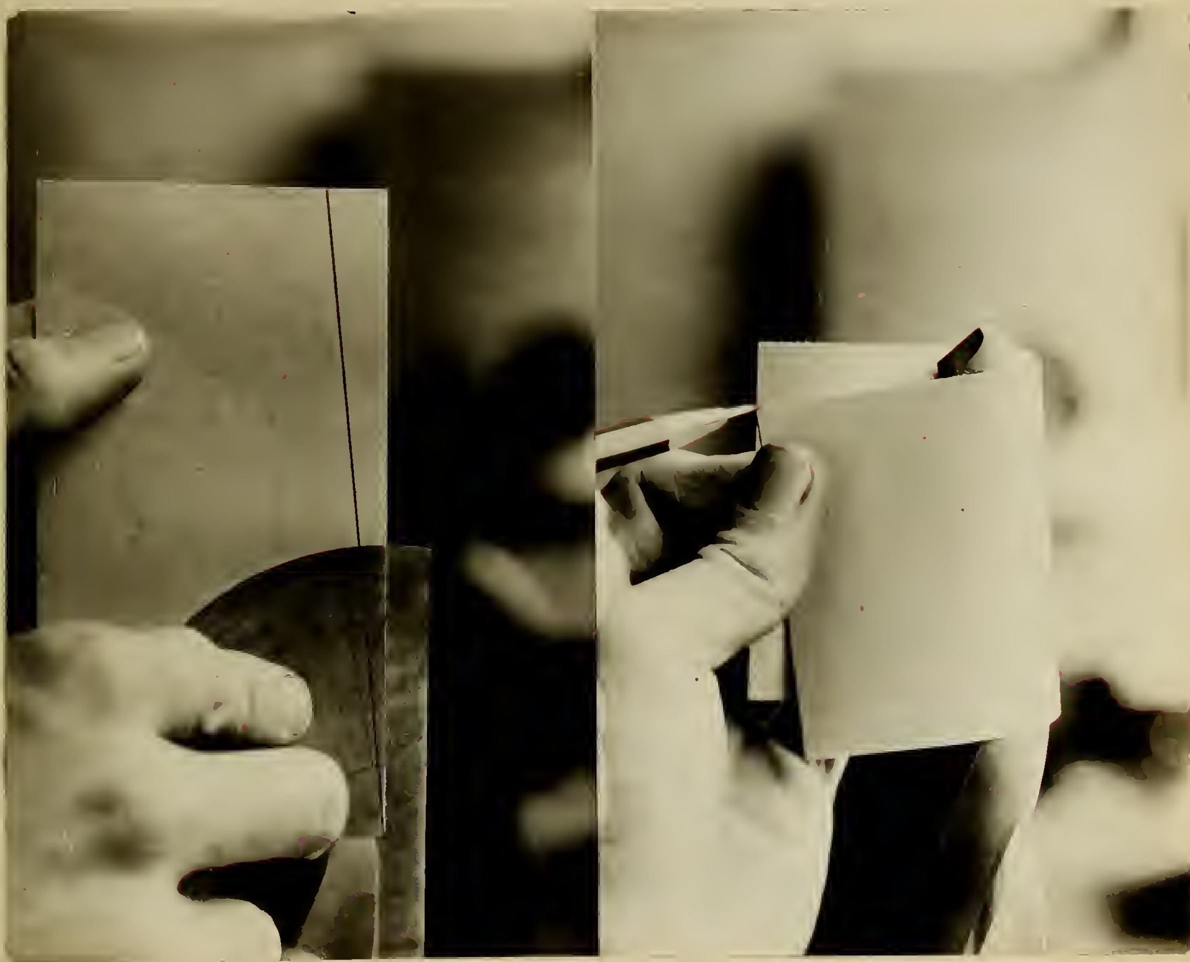
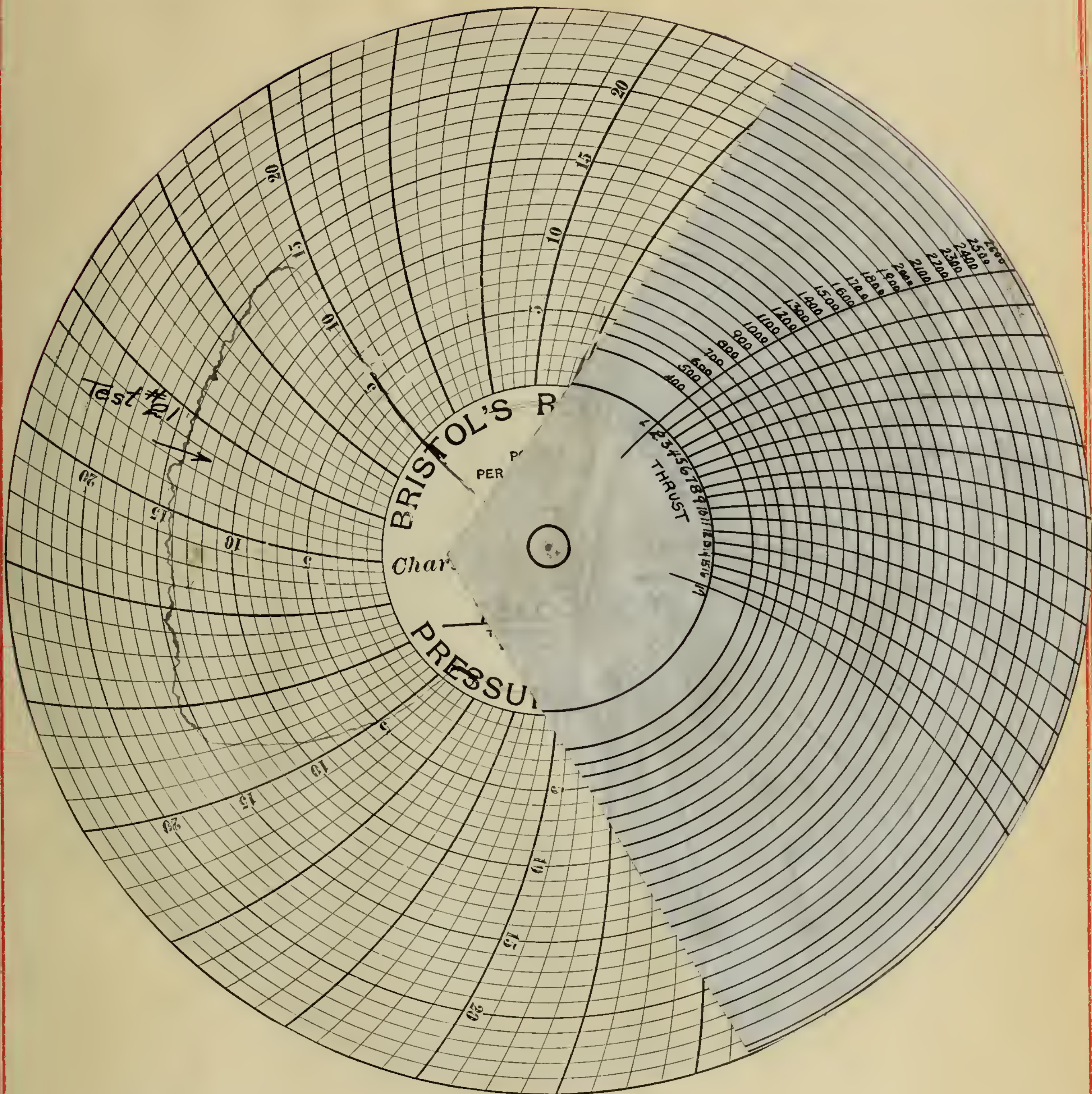


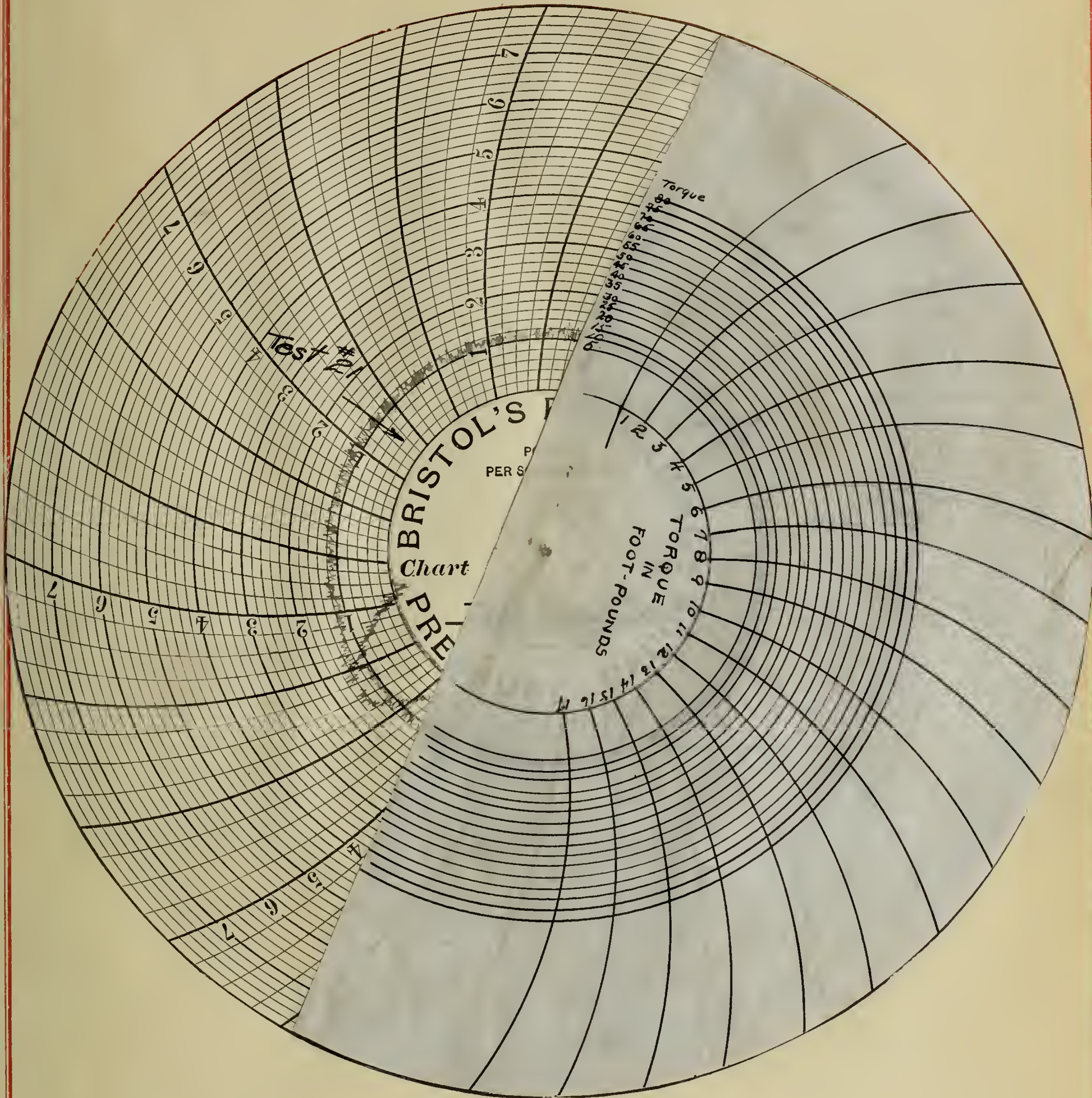
Fig. 4.

Method of obtaining the angle of lip clearance.



Card with templet in position to obtain

the value of ordinates.



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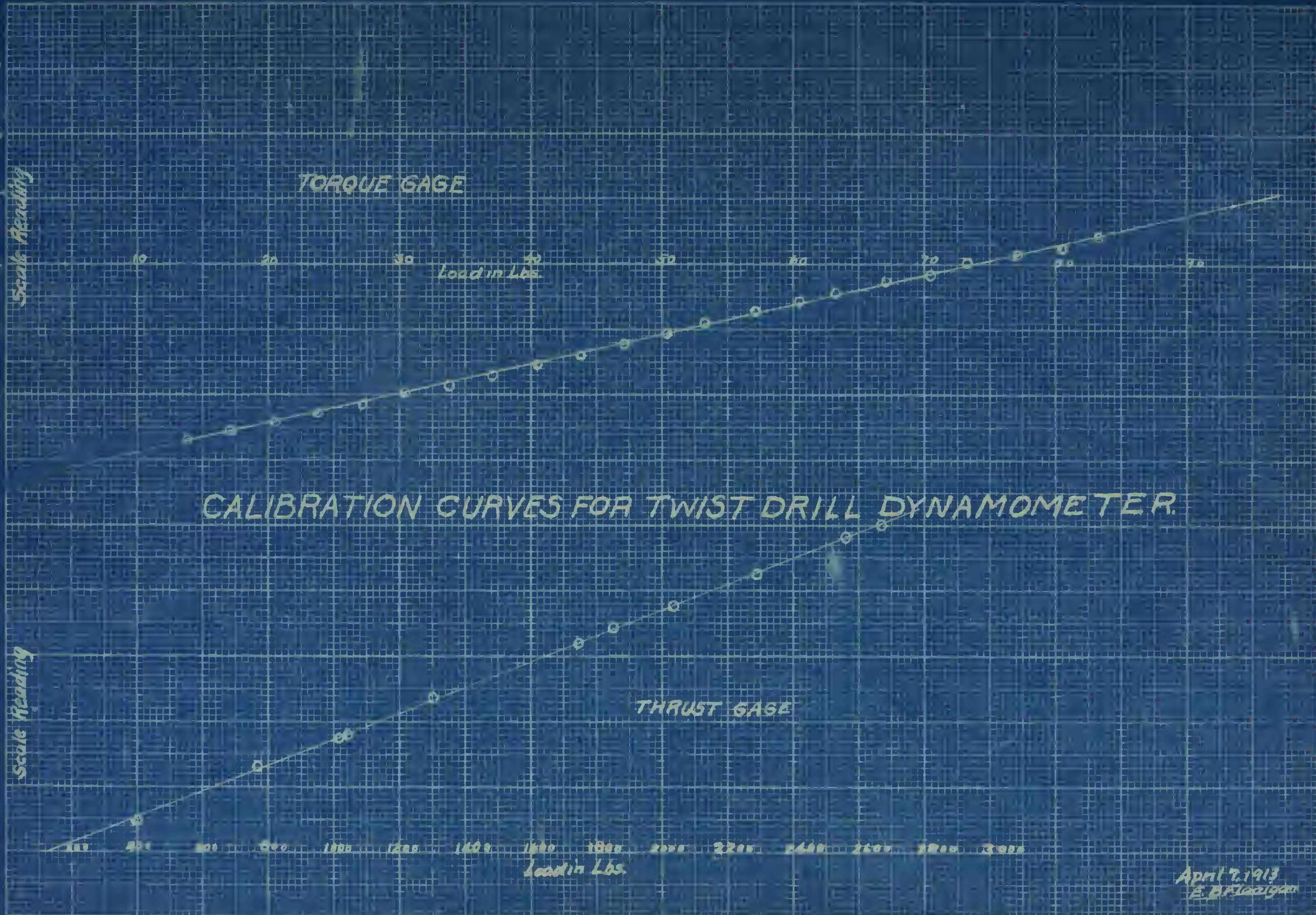

CALIBRATION CURVES FOR TWIST DRILL DYNAMOMETER.
TORQUE GAGE
THRUST GAGE
Scale Reading
Load in Lbs.
Scale Reading
Load in Lbs.
April 7, 1913

TABLE OF DRILLS.

No.	Maker	Trade Name	Type	Clearance Angle	Angle of Point.
1.	New Process T.D.Co.	Reliance	H.S.Milled	$4^\circ 00'$	$59^\circ 30'$
2.	Detroit T.D.Co.		H.S.Milled	$7^\circ 10'$	$61^\circ 00'$
3.	Celfor T.D.Co.	Type D.	H.S.Milled	$4^\circ 10'$	$63^\circ 30'$
4.	Celfor T.D.Co.	Type B.	H.S.Milled	$6^\circ 00'$	$63^\circ 00'$
5.	Whitman and Barnes Co.	"Norka"	Flat Twisted	$4^\circ 55'$	$59^\circ 30'$
6.	Pratt and Whitney		Flat Twisted	$4^\circ 50'$	$59^\circ 30'$
7.	Union T.D.Co.		H.S.Milled	$4^\circ 55'$	$60^\circ 00'$
8.	Lincoln Williams T. D. Co.	"Pioneer"	H.S.Flat twisted	$6^\circ 10'$	
9.	Lincoln Williams T. D. Co.		H.S.Milled		

RESULTS OF TESTS.

Drill	Test	Feed in. per rev.	R.P.M.	Torque	Thrust	Feed in. per min.	H.P.	Duty
1	9	.007	244	8.88	1020	1.71	.4571	1120
1	3	.010	138	6.4	691	1.38	1.709	5220
1	4	.010	136	6.35	790	1.36	1.672	5180
1	11	.010	236	14.3	1185	2.36	.7137	12650
1	13	.013	203	18.1	1880	2.64	.714	11180
1	14	.013	222	7.5	1425	2.89	.3315	4620
2	18	.010	236	6.62	1054	2.36	.524	8210
2	19	.010	240	5.35	1012	2.40	.305	5360
2	20	.013	240	8.23	1095	3.12	.452	6240
2	21	.018	240	9.95	1425	4.32	.516	4270
5	22	.007	224	15.6	1474	1.56	.7363	1970
5	23	.007	232	12.7	1497	1.62	.626	16050
5	27	.007	236	15.6	1422	1.65	.819	19300
5	24	.010	212	19.2	1562	2.12	.860	17050
5	25	.013	212	21.6	1602	2.56	.989	15010
5	26	.013	220	29.5	1897	2.86	1.501	20150
7	27	.007	254	12.34	1005	1.90	1.650	14360
7	28	.010	238	21.08	1395	2.38	1.039	18350
8	32	.010	248	7.14	825	2.48	.387	6560
8	34	.013	246	7.47	1005	3.20	.431	5560
8	35	.018	248	15.2	1356	4.47	.870	8190
9	36	.007	248	4.97	619	1.73	.261	6330
9	37	.010	248	6.73	904	2.48	.353	6020
9	38	.013	234	12.51	956	3.04	.631	8720
10	41	.007	146	7.45	638	1.09	.211	8100
Shop	1	.010	119	10.24	1018	1.19	.262	9270
Shop	2	.013	119	15.75	1157	1.54	.402	10950
Shop	39	.007	110	3.04	604	.77	.769	4250
Shop	40	.010	108	3.75	722	1.08	.773	3000